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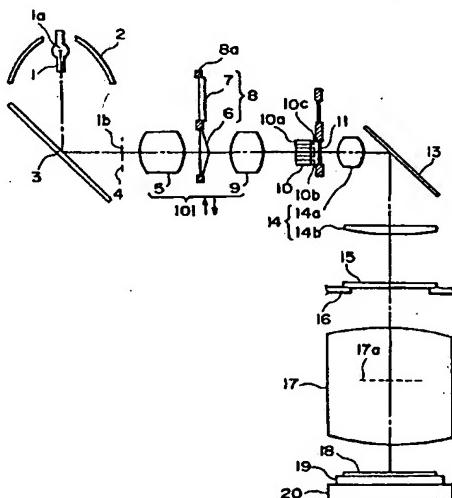
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(54) Illumination device for projection exposure apparatus.

(57) An illumination device (1-14), includes a secondary light source forming system (101) having a deflecting member (6) with a conical light deflecting surface for transforming received light into substantially ring-like light, the secondary light source forming system forming a ring-like secondary light source by using the ring-like light; and an optical system (13,14) for projecting divergent lights from portions of the secondary light source obliquely onto a surface (15) to be illuminated so that the projected lights are superposed one upon another on the surface.



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FIELD OF THE INVENTION AND RELATED ART

This invention relates to an illumination device and a projection exposure apparatus using the same. More particularly, the invention is concerned with an illumination device usable in a microdevice manufacturing exposure apparatus (called a stepper) for illuminating a pattern formed on a reticle in a manner easily attaining high resolution. In another aspect, the invention is concerned with a projection exposure apparatus using such an illumination device.

Semiconductor device manufacturing technology has recently been advanced significantly and, along this, the fine processing technique has been improved considerably. Particularly, the optical processing technique has pressed the fine processing into a submicron region, with manufacture of a device of 1-megabit DRAM. A Conventionally adopted method for improving the resolution is mainly to enlarge the numerical aperture (NA) of an optical system while fixing an exposure wavelength. Recently, however, it has been proposed and practiced to use an exposure wavelength of i-line in place of g-line, in an attempt to improving the resolution in accordance with an exposure method using an ultra-high pressure Hg lamp.

Along the advancement of using g-line or i-line as the exposure wavelength, the resist process itself has been advanced. Such improvements in the optical system and in the process together have accomplished rapid advancement of optical lithograph.

Generally it is known that the depth of focus of a stepper is in inverse proportion to the square of the NA. It means that enhancing the resolution into a submicron order necessarily results in a problem of decreased depth of focus.

In consideration of this problem, many proposals have been made to use shorter wavelengths, as represented by an excimer laser, for enhancement of the resolution. It is known that the effect of using a shorter wavelength is in inverse proportion to the wavelength, and the shorter the wavelength is, the deeper the depth of focus is.

On the other had, independently of using light of shorter wavelength, many proposals have been made to use a phase shift mask (phase, shift method), in an attempt to improving the resolution. According to this method, a mask of conventional type is locally provided with a thin film that imparts to light incident on it a phase shift of 180 deg. relative to the light incident on the remaining portion. An example has been proposed by Levenson of IBM corporation. Here, if the wavelength is denoted by λ , the parameter is denoted by k_1 , and the numerical aperture is denoted by NA, then the resolution RP can be give by:

$$RP = k_1 \lambda / NA$$

It is known that the parameter k_1 , whose practical range is usually taken as 0.7 - 0.8, can be improved

to about 0.35 with this phase shift method.

There are many varieties of such phase shift method, as referred to in a paper by Fukuda et al ("Nikkei Microdevices", July 1990, from page 108).

However, there remains many problems in practically using a phase shift mask of spatial frequency modulation type to improve the resolution. Examples are as follows:

- (1) Unestablished technique for forming a phase shift film;
- (2) Unestablished CAD technique optimized to a phase shift film;
- (3) Existence of a pattern to which no phase shift film can be put;
- (4) Necessity of using a negative the resist (in relation to problem (3)); and
- (5) Unestablished technique for inspection and correction.

Under these circumstances, the phase shift mask method can not be easily practiced in the semiconductor device manufacturing processes.

An exposure method and apparatus which attains enhanced resolution through an appropriately structured illumination device, has been proposed in Japanese patent application No. 28631/1991, filed in Japan on Feb. 22, 1991, in the name of the assignee of the subject application.

In this exposure method and apparatus, such an oblique projection illumination system is adopted, wherein a particular attention is paid to a high spatial frequency region around k_1 factor of 0.5. this illumination system assures a deep depth of focus in the high spatial frequency region.

SUMMARY OF THE INVENTION

Practical semiconductor device manufacturing processes include on one hand a process wherein high resolution of a pattern is required and, on the other hand, a process wherein a not so high resolution of a pattern is required. Thus, the present invention aims to provide a projection exposure apparatus which can meet the requirement of various resolution performances to be satisfied in various processes.

In a first aspect, the present invention provides a variable or adaptable illumination device or a projection exposure apparatus using the same, by which a suitable illumination method appropriate to the resolution actually required can be selectively assured, preferably while maintaining the efficiency of utilization of light.

In accordance with another aspect of the present invention, there is provided an illumination device in which a light emitting portion is disposed in the neighbourhood of a first focal point of an elliptical mirror. By using the light from the light emitting portion and through the elliptical mirror, an image of the light emitting portion is formed in the neighbourhood of a sec-

ond focal point of the elliptical mirror. Light from the image of the light emitting portion is projected through an optical integrator having a plurality of small lenses disposed two-dimensionally to illuminate a surface to be illuminated. An optical device is disposed demountably out of the light path, between the elliptical mirror and the integrator, to deflect the light in a predetermined direction, to thereby change the light intensity distribution at the light entrance surface of the integrator.

In accordance with another aspect of the present invention, there is provided an illumination device in which a light emitting portion is disposed in the neighbourhood of a first focal point of an elliptical mirror. By using the light from the light emitting portion and through the elliptical mirror, an image of the light emitting portion is formed in the neighbourhood of a second focal point of the elliptical mirror. This image is imaged again by an imaging system on the light entrance surface of an optical integrator having a plurality of small lenses disposed two-dimensionally; and a surface to be illuminated is illuminated with the light from the exit surface of the integrator. An optical device is disposed demountably out of the light path, adjacent to the pupil plane of the imaging system, to deflect the light in a predetermined direction, to thereby change the light intensity distribution at the light entrance surface of the integrator. In accordance with a further aspect of the present invention, there is provided an illumination device in which light from a light source is projected through an optical integrator having small lenses disposed two-dimensionally to illuminate the surface to be illuminated. Between the light source and the integrator, an optical device for deflecting light in a predetermined direction is demountably inserted to the light path, to thereby change the light intensity distribution at the entrance surface of the integrator.

In accordance with a further aspect of the invention, there is provided an illumination device in which a light emitting portion is disposed in the neighbourhood of a first focal point of an elliptical mirror. By using the light from the light emitting portion and through the elliptical mirror, an image of the light emitting portion is formed in the neighbourhood of a second focal point of the elliptical mirror. Light from the image of the light emitting portion is projected through an optical integrator having a plurality of small lenses disposed two-dimensionally to illuminate a surface to be illuminated. An optical device including at least two prism members is disposed demountably out of the light path, between the elliptical mirror and the integrator, to deflect the light in a predetermined direction, so as to allow selection of a first state in which light intensity distribution is rotationally symmetric, having higher intensity at its central portion than at the peripheral portion is defined at the entrance surface of the integrator and a second state in which the

light intensity distribution having higher intensity at the peripheral portion than at the central portion is defined at the entrance surface of the integrator.

5 In another aspect, the invention provides a method of manufacturing microdevices such as semiconductor memories, liquid crystal panels, magnetic heads or CCDs, for example, using an illumination device such as above.

10 In a further aspect, the invention provides an exposure apparatus for manufacture of microdevices that uses an illumination device such as above.

The deflecting member usable in the present invention may be of the type that it refracts light at its light deflecting surface to shape or divide the light, or 15 that it reflect the light at its deflecting surface to shape or divide the light.

These and other aspects, features and advantages of the present invention will become more apparent upon a consideration of the following description 20 of exemplary embodiments of the present invention taken in conjunction with the accompanying drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

- 25 Figure 1 is a schematic view of a main portion of a first embodiment of the present invention. In shape this light source has a predetermined figure.
- Figures 2A, 2B and 2C are schematic views, respectively, for explaining a portion of Figure 1.
- 30 Figures 3A, 3B and 3C are schematic views, respectively, for explaining a portion of Figure 1.
- Figure 4 is a schematic view for explaining the optical function of a lens system 9 of Figure 1.
- Figure 5 is a schematic view for further explaining the optical function of the lens system 9 of Figure 1.
- 35 Figure 6 is a schematic view for further explaining the optical function of the lens system 9 of Figure 1.
- Figures 7A and 7B are schematic views, respectively, of a modified form of prism member usable in the present invention.
- 40 Figures 8A and 8B are schematic views, respectively, of a further modified form of prism member usable in the present invention.
- Figure 9 is a schematic view of a portion of a second embodiment of the present invention.
- 45 Figures 10A - 10C are schematic views, respectively, each for explaining a portion of a third embodiment of the present invention.
- Figures 11A and 11B are schematic views, respectively, each for explaining the optical function of the third embodiment.
- 50 Figures 12A and 12B are schematic views, respectively, each for further explaining the optical function of the third embodiment.
- Figures 13A and 13B are graphs, respectively, each showing an example of light intensity distribution in the third embodiment of the present invention.
- Figures 14A and 14B are graphs, respectively,

each showing a further example of light intensity distribution in the third embodiment of the present invention.

Figures 15A - 15C are schematic views, respectively, each showing a main portion of a fourth embodiment of the present invention.

Figure 16 is a schematic view of a main portion of a fifth embodiment of the present invention.

Figure 17 is a schematic view of a main portion of a sixth embodiment of the present invention.

Figure 18 is a schematic view for explaining a portion of Figure 17.

Figure 19 is a schematic view for further explaining a portion of Figure 17.

Figures 20A - 20C are schematic views, respectively, each for explaining the state of incidence of light upon a light entrance plane 10a of an optical integrator 10 of Figure 17.

Figure 21 is a schematic view of an apertured stop.

Figure 22 is a schematic view of a main portion of a seventh embodiment of the present invention.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Figure 1 is a schematic view of an illumination device and a projection exposure apparatus using the same, according to an embodiment of the present invention. In this embodiment, the invention is applied to a reduction projection type exposure apparatus, called a stepper. This exposure apparatus can be used for manufacture of microdevices such as semiconductor memories, CCDs, liquid crystal panels or magnetic head, for example.

Denoted in the drawing at 1 is a light source such as a high luminance ultra high pressure Hg lamp, for example, for emitting ultraviolet light or deep UV light. The light source 1 has its light emitting portion 1a disposed adjacent to the first focal point of an elliptical mirror 2.

The light emanating from the light source 1 is reflected and collected by the elliptical mirror 2, and then it is reflected by a cold mirror 3 by which an image 1b of the light emitting portion 1a (an image of light source) is formed in the neighbourhood of the second focal point 4 of the elliptical mirror 2. The cold mirror 3 has a multilayered film and it mainly serves to transmit infrared light but to reflect ultraviolet light.

Denoted at 101 is an imaging system having two lens systems 5 and 9. It serves to image the light source image 1b, formed in the neighbourhood of the second focal point 4, upon an entrance plane 10a of an optical integrator 10 through the cooperation of an optical device 8. The optical device 8 comprises a prism member 6 having a conical prism, for deflecting received light to a predetermined direction, and a parallel flat plate 7 for projecting received light directly.

Denoted at 8a is a holding member by which the prism member 6 and the parallel plate 7 of the optical device 8 can be alternately and selectively placed on the light path. When the parallel plate 7 is on the path, the imaging system 101 is defined as an telecentric system on the exit side. The optical device 8 is disposed in the neighbourhood of the pupil plane of the imaging system, where the opening of the elliptical mirror is imaged.

The optical integrator 10 comprises a plurality of small lenses which are arrayed two-dimensionally, and it serves to define a secondary light source 10c in the neighbourhood of the exit surface 10b thereof. Denoted at 11 is a stop member having a plurality of apertures. The stop member is provided with a mechanism by which the shape of aperture on the light path can be changed. To the secondary light source 10c, the stop member 11 is disposed in such region in which discrete secondary light source elements do not overlap.

Denoted at 14a is a lens system for collecting the light from the exit surface 10b of the optical integrator 10 and for illuminating, through the stop member 11 and a mirror 13 as well as a collimator lens 14b, a reticle (surface to be illuminated) 15 placed on a reticle stage 16. The lens system 14a and the collimator lens 14b constitute a condensing lens system 14. Denoted at 17 is a projection optical system for projecting, in a reduced scale, a pattern formed on the reticle 15 upon the surface of a wafer 18 which is placed on a wafer chuck 19. Denoted at 20 is a wafer stage on which the wafer chuck 19 is mounted. In this embodiment, with the condensing lens system 14, an image of the secondary light source 10c formed in the neighbourhood of the exit surface 10b of the optical integrator 10, is formed in the neighbourhood of a pupil 17a of the projection optical system 17.

Next, description will be made on the manner of changing the light intensity distribution of the image of the secondary light source, which image is formed at the pupil plane 17a of the projection optical system 17, in accordance with the present embodiment by changing the light intensity distribution at the light entrance surface 10a of the optical integrator 10 through the optical device 8.

Figures 2A and 3A each illustrates the light path from the elliptical mirror 2 (Figure 1) to the optical integrator 10, the path being extended. The mirror 3 is not shown in Figure 2A or 3A. The illustrations of Figures 2A - 2C and 3A - 3C explain that the light intensity distribution upon the entrance surface 10a of the optical Integrator 10 is changed by alternately selecting the elements 6 and 7 of the optical device 8.

Figures 2A - 2C correspond to a case where the parallel plate 7 of the optical device 8 is disposed on the light path, whereas Figures 3A - 3C correspond to a case where the prism member 6 of the optical device 8 is disposed on the light path.

The illumination system of Figure 2A is adapted for a first state of projection in which a very high resolution is not required but in which a larger depth of focus is assured. The illumination system of Figure 3A is adapted for a second state of projection in which a high resolution is required mainly.

Figures 2C and 3C each is a schematic representation of light intensity distribution upon the light entrance surface 10a of the optical integrator 10. The zone depicted by hatching in the drawings denotes the region of higher light intensity, as compared with the remaining region. Figures 2B and 3B illustrate distribution of light intensity I along the X-axis direction (Figure 2C or 3C).

In Figure 2A, the parallel plate 7 of the optical device 8 is disposed on the light path, and the light source image 1b as formed at the second focal point 4 of the elliptical mirror 2 is imaged by the imaging system 101 upon the light entrance surface 10a of the optical integrator 10. Here, as seen in Figure 2B, the light intensity distribution in section upon the light entrance surface 10a of the optical integrator 10 has an approximately Gaussian shape which is rotationally symmetric.

In Figure 3A, the prism member 6 of the optical device 8 is placed on the light path, and the light source image (point image) 1b formed at the second focal point 4 of the elliptical mirror 2 is imaged, into a ring-like shape, on the light entrance surface 10a of the optical integrator 10 by the imaging system 101. The light intensity distribution on the light entrance surface 10a of the integrator 10 has a ring-like shape such as shown in Figures 3B or 3C wherein the light intensity is lower at the optical axis portion but is higher at the peripheral portion. Why this is so will now be explained below.

Figure 4 schematically illustrates the disposition of the parallel flat plate 7, the lens system 9 and the light entrance surface 10a of the optical integrator 10 of Figure 2A. In this embodiment, these elements are so disposed that the optical distance between the parallel plate 7 and the forward principal point of the lens system 9 as well as the optical distance between the backward principal point of the lens system 9 and the light entrance surface 10a of the integrator 10 are, if the focal length of the lens system 9 is denoted by f_0 , both equal to a distance f_0 .

Here, the incidence height t_1 , from the optical axis, of the light emanating from the parallel plate 7 with an angle α_0 and impinging on the light entrance surface 10a is expressed as follows:

$$t_1 = f_0 \tan \alpha_0$$

If the height, from the optical axis, of the outermost light passing through the parallel plate 7 is denoted by S_0 , then the angle β of incidence upon the light entrance surface 10a of the integrator is given by:

$$\beta = \tan^{-1}(S_0/f_0)$$

It is seen therefrom that, by deflecting the angle of

light at the position of the parallel plate 7 (i.e., forward focal plane of the lens system 9), it is possible to change only the position of incidence of light upon the entrance surface 10a of the optical integrator without changing the angle of incidence.

Based on the optical principle described, in the present embodiment, by interchanging the parallel plate 7 by the prism member 6 comprising a conical prism, the light intensity distribution on the entrance surface 10a of the integrator 10 is changed into a ring-like intensity distribution having lower intensity at the optical axis portion and higher intensity at the peripheral portion.

Since the light intensity distribution on the entrance surface 10a of the integrator 10 corresponds to the light intensity distribution of an effective light source which is defined at the pupil plane 17a of the projection optical system 17, by using the prism member 6 in place of the parallel plate 7 such an effective light source having light intensity distribution having lower intensity at a central portion (optical axis portion) and higher intensity at a peripheral portion is defined on the pupil plane of the projection optical sys-

tem. In this embodiment, the stop member 11 is provided in the neighbourhood of the exit surface 10b of the optical integrator 10. This stop member has a plurality of apertures and is provided with a mechanism for changing, as desired, the aperture shape thereof. The aperture shape which is variable is predetermined and it corresponds to the shape of the secondary light source to be formed at the pupil plane 17a of the projection optical system 17. For example, the stop member may have a ring-like aperture of a property for passing a larger quantity of light at its peripheral portion than at its central portion.

In this embodiment, the selection of the prism member 6 of the optical device 8 singly or the selection of the prism member 6 together with the changing the aperture shape of the stop member 11 in combination, assures a desired shape of effective light source while a Stairing high efficiency of light utilization.

It is to be noted that the provision of the stop member 11 is not a requisition in this embodiment.

With the arrangement of this embodiment as described above, for a reticle 15 pattern having a relatively large minimum linewidth, the structure shown in Figure 2A is selected (like an illumination system of conventional type), whereby a Gaussian shape light intensity distribution is provided at the entrance surface 10a of the optical integrator 10 (first state).

On the other hand, for a pattern having a relatively small minimum linewidth, the structure shown in Figure 3A is selected to provide a ring-like light intensity distribution at the entrance surface 10a of the integrator 10. Also, the aperture shape of the stop member 11 is changed. By this, an illumination device

for high resolution projection is assured (second state).

The insertion of the parallel plate 7 in the first state of Figure 2A is to minimize the difference in optical path length between the lens systems 5 and 9, as compared with that in the case where the prism member 6 is inserted in the second state. If the prism member 6 has a small thickness or is a slight change in optical path length between the lens systems 5 and 9 does not influence the optical performance of the optical integrator 10 or of any other optical elements following it, the parallel plate 7 may be omitted.

Figures 5 and 6 are schematic representations for explaining the relationship of the incidence height (heights t_1 and t_2 from the optical axis) at the entrance surface 10a of the optical integrator 10, relative to the position (exit heights S_1 and S_2) and deflection angle (α_1 and α_2) of light passing through the parallel plate 7, where in the present embodiment the focal length of the lens system 9 constituting the imaging system 101 is changed.

If in Figure 5 the focal length of the lens system 9 is f_1 , then $t_1 = f_1 \tan \alpha_1$ applies. Also, in Figure 6, if the focal length of the lens system 9 is f_2 , then $t_2 = f_2 \tan \alpha_2$ applies.

It is seen from these equations that if the focal length of the lens system 9 is made large then it is possible to obtain, at the entrance surface 10a of the optical integrator 10, an incidence position t_1 of desired height with a small deflection angle α_1 at the position of the parallel plate 7. This means that if the focal length f of the lens system 9 is made large then it is possible to make small the angle of the prism member 6 (prism angle) in the second state. This assures an imaging system 101 of smaller aberration. Practically, in consideration of the size of the prism member 6, the focal length of the lens system 9 may be so set to define a prism angle of 5 - 20 deg.

The prism member 6 of the optical device of the present invention is not limited to a conical prism. It may have any shape provided that it has a function for deflecting received light in a predetermined direction. For example, pyramidal prisms such as shown in Figures 8A and 8B may be used.

Figures 7B and 8B schematically illustrate light intensity distribution on the entrance surface 10a of the integrator 10 where the prism member such as shown in Figure 7A or 8A is used. The zones depicted by hatching denote regions of higher intensity as compared with the remaining region.

It is possible in the present invention to use three or more types of interchangeable optical members such as prisms and a parallel plate, rather than only two optical members of the prism 6 and the parallel plate 7 are interchanged as in the present embodiment.

Further, the pyramidal prism such as shown in Figure 7A may be rotated about the optical axis, for

smoothing with respect to time, to provide a ring-like light intensity distribution such as shown in Figure 3C.

Still further, the light source 1 may be displaced along the optical axis concurrently with the interchange of the prism member, to change the size of the higher light intensity region.

Figure 9 is a schematic view of a main portion of a second embodiment of the present invention.

In this embodiment, as compared with the first embodiment of Figure 1, a half mirror 30 is disposed on the light path at the position before (light source 1 side) of the optical integrator 10, so that a portion of the light from the imaging system 101 is directed to a photodetector 31 which may comprise a CCD or a quadrant sensor. The remaining portion is of the same structure as of the first embodiment.

In this embodiment, the light intensity distribution at the light entrance surface 10a of the optical integrator 10 is measured indirectly to monitor the same.

This allows adjustment of the imaging system 101 while monitoring changes in light intensity and/or light

intensity distribution at the entrance surface 10a of the integrator 10. In this embodiment, a mechanism 60 for rotating the optical member 6 about the optical axis or, for shifting the same with respect to the optical axis, may be used. This enables to change the light intensity distribution at the entrance surface 10a of the integrator 10 into a desired shape easily.

Figures 10A is a schematic view of a main portion of a third embodiment of the present invention. In this embodiment, as compared with the first embodiment of Figure 1, in addition to the insertion of the prism member 6 into the light path, the lens system 9 is replaced by a lens system 33 of a different focal length which is disposed at the entrance face 10a side of the optical integrator 10. The remaining portion is of the same structure as of the first embodiment.

In this embodiment, light is collected to a region narrower than the entrance surface 10a of the integrator 10, and light intensity distribution of a desired shape is obtained.

Referring now to Figures 11A, 11B, 12A and 12B, the optical function of this embodiment will be explained.

Figures 11A - 12B schematically illustrate the light path from the optical device 8 (prism 6 and parallel plate 7) to the integrator 10. Figures 13A, 13B, 14A and 14B show light intensity distribution at the entrance surface 10a of the integrator 10, defined by using the prism member 6 or the parallel plate 7.

Figure 11A shows the arrangement where in the first embodiment conventional illumination is to be done. Generally, the angle of light rays that can enter the optical integrator is determined and, in the example of Figure 11A, the angle is θ_1 . Thus, the optical system before the integrator 10 is designed so that the angle of incidence upon the integrator 10 be-

comes not greater than the angle θ . Here, in the light intensity distribution at the entrance surface 10a of the integrator 10, the degree of convergence is limited due to Lagrange's invariant. For example, it is not possible to improve the degree of convergence beyond that of Figure 13A. An attempt to obtaining higher degree of convergence simply ends in that the angle of incidence upon the integrator 10 goes beyond the angle θ .

Figure 11B shows the state where in the first embodiment the prism member 6 is inserted into the light path. Figure 13B shows corresponding light intensity distribution at the entrance surface 10a. Here, the maximum incidence angle of the light upon the entrance surface 10a, at the point S₁, is θ_1 the same as the Figure 11A example. However, the effective light angle of the light actually enters is θ_2 .

As seen from Figure 12A, with the provision of an optical device 32 (which may comprise a prism or a field lens) in front of the entrance surface 10a, it is possible to reduce the maximum incidence angle. Figure 14A shows corresponding light intensity distribution at the entrance surface 10a. Figure 12B shows an example wherein the maximum incidence angle is loosened, by shortening the focal length of the optical system from the prism 6 to the optical integrator it is possible to obtain a higher degree of convergence. Figure 12B shows an example wherein the degree of convergence is improved on the basis of such optical principle just described. Corresponding light intensity distribution is shown in Figure 13B. In the example of Figure 12B, the prism member 6 has an enlarged prism angle so as to obtain light intensity distribution of ring-like shape.

In this embodiment, the insertion of the prism member 6 as described causes shift of the angle of incidence at the entrance surface 10a of the integrator 10 while the maximum incidence angle being unchanged. By correcting such shift and optimizing the incidence angle, the incidence angle is loosened. Thus, it becomes possible to increase the degree of convergence to the limit where the incidence angle becomes equal to the critical incidence angle.

Practical means for this end may be using a zoom system for the optical system from the prism member 6 to the integrator 10; using interchangeable optical systems; provision of a prism (conical prism where the prism member 6 comprises a conical prism; a pyramidal prism where the prism member 6 comprises a pyramidal prism) in front of the integrator 10; insertion of an aspherical lens; or appropriate combination of them.

Figures 15A - 15C are schematic views of a portion of a fourth embodiment of the present invention.

In this embodiment, as compared with the first embodiment of Figure 1, the position of the optical device 8 (the position of prism member 6 and/or parallel plate 7) is shifted from the pupil of the imaging system

101 and the focal length of the optical system 9 is changed, to thereby converge the light intensity distribution at the entrance surface 10a of the optical integrator 10. The remaining portion is of the same structure as of the first embodiment.

In Figures 15A - 15C, reference character P denotes the pupil plane of the lens system 9. Figure 15A shows the first state of illumination in the first embodiment. The angle of incidence upon the integrator 10 is θ . Figure 15B shows the second state of illumination in the first embodiment, and the, incidence angle is θ the same as in the Figure 11A example. Here, if the prism member 6 is shifted from the pupil plane P and the beam diameter on the plane P is reduced such as shown in Figure 15C, then it is possible to make the incidence angle θ' smaller than the angle θ_2 of the Figure 11A and 11B examples. In the present embodiment, in this occasion, the focal length of the lens system 9 is changed so as to assure that the light intensity distribution at the entrance surface 10a of the integrator 10 is collected and convergence locally.

Figure 16 is a schematic view of a main portion of a fifth embodiment of the present invention.

In this embodiment, as compared with the first embodiment of Figure 1, the lens system 5 constituting the imaging system 101 is omitted and the opening 2a of the elliptical mirror 2 is imaged by the lens system 9 upon the entrance surface 10a of the optical integrator 10. Also, the optical device 8 is disposed in the neighbourhood of the second focal point of the elliptical mirror 2. The remaining portion is of the same structure as of the first embodiment.

More specifically, in the embodiment of Figure 1, an image of the light emitting portion 1a of the light source 1 is formed on the entrance surface 10a of the integrator 10, and the optical device 8 is disposed in the neighbourhood of the imaging position of the opening 2a of the elliptical mirror 2 (the position of the image of the opening 2a) which is between the light source 1 and the integrator 10.

In the present embodiment, as compared, the image of the opening 2a of the elliptical mirror 2 is formed on the entrance surface 10a of the integrator 10, and the optical device 8 is disposed at the imaging position of the light emitting portion 1a (the second focal point position of the elliptical mirror 2) which is between the light source 1 and the optical integrator 10.

Thus, in this embodiment, the forward focal point position of the lens system 9 is placed substantially at the second focal point position of the elliptical mirror 2, and by the lens system 9, the light from the light source image 1b at the second focal point is transformed into substantially parallel light which is then directed to the entrance surface 10a of the integrator 10. When the prism member 6 is being inserted and if it is of the type such as shown in Figure 7A, four parallel lights from the lens system 9 are projected on the entrance surface 10a of the integrator 10.

Figure 17 is a schematic view of a main portion of a sixth embodiment of the present invention.

In this embodiment, as compared with the first embodiment of Figure 1, the optical device 8 comprises at least two prism members 6a and 6b disposed along the optical axis and, for changing the light intensity distribution at the entrance surface 10a of the integrator 10, namely, for rendering the illumination system into the second state, the optical device 8 (prism members 6a and 6b) is mounted on the optical axis and, additionally, a portion of the lens system 9a constituting the imaging system 101 is replaced by another lens system 9b so as to reduce the incidence angle of off-axis principal ray to the entrance surface 10a. This is done for efficient utilization of light.

In the illumination method of this embodiment, in the first state the lens system 9a is placed on the light path (the optical device 8 is not used), so as to provide light intensity distribution at the entrance surface 10a of the integrator 10, that is, light intensity distribution at the pupil plane 17a of the projection optical system 17, which distribution is of a rotationally symmetric shape wherein the intensity is higher at the central portion than at the peripheral portion. The second state is defined by placing the optical device 8 (prism members 6a and 6b) on the light path and by replacing the lens system 9a by the lens system 9b having a different focal length. This makes smaller the angle of incidence of the principal ray upon the entrance surface 10a of the integrator 10, whereby at this entrance surface 10a, namely, at the pupil plane 17a of the projection optical system 17, such light intensity distribution in which the intensity is higher in the peripheral portion than in the central portion is provided.

Structural features of this embodiment over the first embodiment will be explained in more detail.

In Figure 17, lens system 5 collects the light from the light source image 1b formed in the neighbourhood of the second focal point 4, and it emits parallel light. The imaging system 101 (lens systems 5 and 9a) is telecentric on the exit side. At least a portion of the collecting lens 14 is made movable along the optical axis, to adjust the light intensity distribution on the reticle 15.

In this embodiment, in accordance with the orientation and/or the linewidth to be resolved of the pattern of the reticle 15, for example, the lens system 9a which is a constituent element of the imaging system 101 is replaced by the optical device 8 (including two prisms 6a and 6b) and the lens system 9b, to change the light intensity distribution at the entrance surface 10a of the integrator 10. Additionally, if necessary the aperture shape of the stop member 11 is changed to change the light intensity distribution of the image of the secondary light source which image is formed at the pupil plane 17a of the projection optical system 17.

Next, the manner of changing in this embodiment the light intensity distribution on the entrance surface 10a of the integrator 10 as well as the light intensity distribution of the image of the secondary light source to be formed on the pupil plane 17a of the projection optical system 17, on the basis of the optical device 8, will be explained.

Figures 18 and 19 each schematically illustrate the light path from the elliptical mirror 2 to the optical integrator 10 of Figure 17, the path being extended. The mirror 3 is not shown in Figure 18 or 19. The illustrations of Figures 18 and 19 explain that the components of the optical device 8 are interchanged to change the light intensity distribution on the entrance surface 10a of the integrator 10.

Figure 18 shows the state in which the lens system 9a is placed on the light path. Figure 19 shows the state in which the lens system 9a is removed and, in place thereof, the prism members 6a and 6b of the optical device 8 and the lens system 9b are placed on the light path:

The illumination system of Figure 18 is in the first state of projection in which a very high resolution is not required but a large depth of focus is assured; as in the illumination method of conventional type. The illumination system of Figure 19 is in the second state of projection according to the present invention, mainly for attaining high resolution. The portion (B) of Figure 18 and the portion (B) of Figure 19 schematically each shows corresponding light intensity distribution on the entrance surface 10a of the integrator 10. The zone depicted by hatching denotes the region of higher intensity as compared with the remaining region. In these illustrations, the distribution of light intensity I along the X-axis direction are depicted.

Figures 20A, 20B and 20C are schematic representations, for explaining the light rays impinging on the optical integrator 10, in the systems of Figure 18 and 19. Reference characters +θ and -θ each denotes the range (angle) of light rays that can enter the optical integrator 10 (that can emerge from the integrator without being eclipsed). Grid portion in each illustration depicts the zone in which the light intensity is higher than that of the light entering the integrator 10.

Figure 18, (A), shows the optical arrangement in ordinary illumination. Here, the light intensity distribution at the entrance face 10a of the integrator 10 is like a Gaussian distribution such as shown in Figure 18, (B). The incidence angle thereof is such as shown in Figure 20A. When in this state the illumination for high resolution is to be done, there may be a method in which a stop 121 having an aperture 121a such as shown in Figure 21 is inserted at the back of or in front of the integrator 10. However, with this method, only the light in the hatched zone of the light intensity distribution of Figure 18, (A), can be used and, therefore, the illuminance decreases considerably.

In this embodiment, in consideration thereof, as shown in Figure 19, (A), the lens system 9a is replaced by the lens system 9b of smaller focal length (the optical components are disposed so that, if the focal length of the lens system 9b is f_{9b} , the optical distance between the prism 6a and the lens system 9b and the optical distance between the lens system 9b and the entrance surface 10a of the integrator 10 are both equal to f_{9b}), such that the light intensity distribution as shown in Figure 19, (B), is provided at the entrance surface 10a of the integrator 10.

Additionally, the prism member 6b having an appropriate prism angle is inserted in front of the integrator 10, by which the incidence angle of light rays (incidence angle of off-axis light) is made smaller such as shown in Figure 20C, this assures efficient impingement or entrance of light into the integrator 10. Thus, almost all the input light can be used for the illumination.

On the basis of the optical principle described above, the present embodiment uses the optical arrangement such as shown in Figure 19, (A); by which illumination for high resolution is assured without a substantial loss of illuminance at the surface to be illuminated.

The prism member 6a, or 6b or pyramidal shaped provided within the imaging system 101 may have an shape such as shown in Figure 8, for example. Of course, it may be a conical prism.

While the embodiment has been explained with reference to an example wherein the lens system 9a of Figure 18 for ordinary illumination is replaced by the lens system 9b of Figure 19 for high resolution illumination, the lens elements of the lens system 9a may be displaced (like a zoom lens system) to define the same condition as by the lens system 9b. Only some of the lens elements may be moved like a zoom lens system or, alternatively, some lens elements may be replaced by different lens elements.

The stop member 121 for high resolution such as shown in Figure 21 may be used as desired, or it may be omitted. Further, while in this embodiment the focal length of the lens system 9a is changed to change the magnification of the imaging system 101, the focal length of the lens system 5 may be changed. Alternatively, both of the focal lengths of the lens systems 5 and 9 may be changed.

In this embodiment, there are cases wherein, in response to the interchange of the ordinary illumination (first state) and the illumination for high resolution (second state), uniformness in illuminance (non-uniformness of illuminance) upon the surface being illuminated changes into axial symmetry. In that occasion, a portion of the optical system 14 may be displaced along the optical axis to change aberration such as distortion to thereby correct the axially symmetric non-uniformness of illuminance upon the surface (reticle 15 surface) to be illuminated.

While in the preceding embodiment the reticle 15 (surface to be illuminated) is disposed just after the optical system 14, an additional imaging system may be disposed between the optical system 14 and the reticle such that a plane which is optically conjugate with the reticle 15 surface with respect to the additional imaging system may be illuminated.

Figure 22 is a schematic view of a main portion of a seventh embodiment of the present invention.

In this embodiment, as compared with the first embodiment of Figure 1, a half mirror 43 is disposed between the integrator 10 and the surface 15 to be illuminated, so as to allow detection of the amount of exposure of the surface being illuminated. The remaining portion is of substantially the same structure as of the first embodiment.

In Figure 22, denoted at 44 is the reticle pattern surface or a plane which is optically conjugate with the reticle pattern surface. Denoted at 45 is a pinhole member which is disposed at a position optically conjugate with the plane 44. Denoted at 33 is a photosensor (e.g., CCD or quadrant sensor).

With this arrangement of the present embodiment, it is possible to monitor the effective light source distribution at the center of the surface being illuminated. Also, in this embodiment it is possible to concurrently monitor, with the photodetector 31, the amount of exposure of the surface being illuminated. While in this embodiment the half mirror 43 is placed between the lens system 13a and the collimator lens 14b, it may be disposed at any position between the integrator 10 and the surface 15.

In accordance with the present invention, in consideration of fineness and/or orientation of a pattern of a reticle to be projected and transferred, an illumination system suited to such pattern can be selected.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.

45 Claims

1. An illumination device, comprising:
secondary light source forming means
having a deflecting member with a conical light
deflecting surface for transforming received light
into substantially ring-like light, said secondary
light source forming means forming a ring-like
secondary light source by using the ring-like light;
and
an optical system for projecting divergent
lights from portions of the secondary light source
obliquely onto a surface to be illuminated so that
the projected lights are superposed one upon an-

other on the surface.

2. A device according to Claim 1, wherein said secondary light source forming means comprises a light source, reflecting means for reflecting the light from said light source and for forming an image of said light source, an optical integrator, and an imaging optical system for re-imaging the light source image, wherein said imaging optical system includes parallelizing means for transforming the light from the light source image into substantially parallel light, and collecting means for collecting the ring like light from said deflecting member substantially into a ring-like shape upon said integrator.
3. A device according to Claim 2, wherein said deflecting member is demountably mounted to the path of light to be received,
4. A device according to Claim 3, wherein said imaging optical system comprises an optical system having a variable imaging magnification.
5. A device according to Claim 3, further comprising means for moving said deflecting member in a direction intersecting with the optical axis of said imaging optical system.
6. A device according to any of claims 2 to 5, further comprising means for rotating said deflecting member about the optical axis.
7. A device according to any of claims 2 to 5, further comprising a second light deflecting member for reducing the angle of incidence of the ring-like light upon said integrator.
8. A device according to Claim 7, wherein said second light deflecting member comprises a prism having a conical light deflecting surface.
9. A device according to Claim 7, wherein said second light deflecting member comprises a field lens.
10. An exposure apparatus for exposing a substrate to a mask with light, said apparatus including an illumination device according to any of claims 1 to 9.
11. An apparatus according to Claim 10, further comprising means for imaging a pattern of the mask onto the substrate.
12. A device manufacturing method including a step of exposing a workpiece to a mask, said method comprising the steps of:

- 5 projecting light onto a light deflecting surface of conical shape to produce substantially ring-like light;
- 10 forming a secondary light source by using the ring-like light;
- 15 projecting lights from portions of the secondary light source obliquely onto the mask so that the lights are superposed one upon another on the mask,
13. A method according to Claim 12, wherein a pattern of the mask is imaged on the workpiece.
14. An illumination device, comprising:
 - a light source;
 - an optical integrator;
 - an imaging optical system for imaging said light source, said imaging optical system including (i) parallelizing means for transforming light from said light source into substantially parallel light; (ii) a deflecting member having a light deflecting surface of one of conical shape or pyramidal shape, for receiving the light from said parallelizing means; and (iii) light collecting means for collecting ring-like light or a plurality of lights from said deflecting member into a substantially ring-like shape or a plurality of light spots upon said optical integrator;
 - an optical system for projecting lights from portions of a secondary light source formed by said integrator obliquely upon a surface to be illuminated so that the lights are superposed one upon another on the surface; and
 - means for changing a positional relationship between an apex of said light deflecting surface and the optical axis.
15. A device according to Claim 14, wherein said deflecting member is demountably mounted to the path of light from said light source.
16. A device according to Claim 15, wherein said imaging optical system comprises an optical system having a variable imaging magnification.
17. A device according to claim 14, 15 or 16, further comprising means for rotating said deflecting member about the optical axis.
18. A device according to any of claims 14 to 17, further comprising a second light deflecting member for reducing the angle of incidence of the ring-like light or the plurality of lights upon said integrator.
19. A device according to Claim 18, wherein said second light deflecting member comprises a prism having a conical light deflecting surface.

- 20.** A device according to Claim 18, wherein said second light deflecting member comprises a field lens.
- 21.** An exposure apparatus for exposing a substrate to a mask with light, said apparatus including an illumination device according to any of claims 14 to 20.
- 22.** An apparatus according to Claim 21, wherein said imaging optical system comprises first image forming means for reflecting light from said light source and for forming an image of said light source, and second image forming means for re-imaging the light source image, wherein said second image forming means includes said parallelizing means, said deflecting member and said collecting means.
- 23.** An apparatus according to claim 21 or 22, further comprising means for imaging a pattern of the mask onto the substrate.
- 24.** A device manufacturing method including a step of exposing a workpiece to a mask with light; said method comprising the steps of: projecting light to a light deflecting surface of conical shape or pyramidal shape to form ring-like light or a plurality of lights; forming a secondary light source by using the ring-like light or the plurality of lights; wherein, in said projection step and said secondary light source forming step, the positional relationship between an apex of the light deflecting surface and the optical axis is changed to provide the secondary light source of a desired intensity distribution; and projecting divergent lights from portions of the secondary light source obliquely upon the mask so that the lights are superposed one upon another on the mask.
- 25.** A method according to Claim 24, wherein a pattern of the mask is imaged on the workpiece.
- 26.** An illumination device, comprising:
- a light source;
 - an optical integrator;
 - an imaging optical system for imaging said light source, said imaging optical system including (i) parallelizing means for transforming light from said light source into substantially parallel light, (ii) a first deflecting member having a light deflecting surface of one of conical shape or pyramidal shape, for receiving the light from said parallelizing means, and (iii) light collecting means for collecting ring-like light or a plurality of lights from said first deflecting member into a substantially ring-like shape or a plurality of light spots upon said optical integrator; and
 - an optical system for projecting lights from portions of a secondary light source formed by said integrator obliquely upon a surface to be illuminated so that the lights are superposed one upon another on the surface;
- wherein said collecting means of said imaging optical system includes a second deflecting member effective to reduce the angle of incidence upon said integrator of the ring-like light or of the plurality of lights; and
- wherein said first and second deflecting members are provided in a pair demountably mounted.
- 27.** A device according to Claim 26, wherein said imaging optical system comprises an optical system having a variable imaging magnification.
- 28.** A device according to claim 26 or 27, further comprising means for moving said first deflecting member in a direction intersecting with the optical axis of said imaging optical system.
- 29.** A device according to claim 26, 27 or 28 further comprising means for rotating said first deflecting member about the optical axis.
- 30.** A device according to any of claims 26 to 29, wherein each of said first and second deflecting members comprise a prism having a conical light deflecting surface.
- 31.** A device according to any of claims 26 to 29, wherein each of said first and second deflecting members comprise a prism having a pyramidal light deflecting surface.
- 32.** A device according to any of claims 26 to 29, wherein said second deflecting member comprises a field lens.
- 33.** A device according to any of claims 26 to 32, wherein said imaging optical system comprises first image forming means for reflecting light from said light source and for forming an image of said light source, and second image forming means for re-imaging the light source image, wherein said second image forming means includes said parallelizing means, said deflecting member and said collecting means.
- 34.** An exposure apparatus for exposing a substrate to a mask with light, said apparatus comprising:
- a light source;
 - an optical integrator;
 - an imaging optical system for imaging said

light source, said imaging optical system including (i) parallelizing means for transforming light from said light source into substantially parallel light, (ii) a first deflecting member having a light deflecting surface of one of conical shape or pyramidal shape, for receiving the light from said parallelizing means, and (iii) light collecting means for collecting ring-like light or a plurality of lights from said first deflecting member into a substantially ring-like shape or a plurality of light spots upon said optical integrator; and

an optical system for projecting lights from portions of a secondary light source formed by said integrator obliquely upon a surface to be illuminated so that the lights are superposed one upon another on the surface;

wherein said collecting means of said imaging optical system includes a second deflecting member effective to reduce the angle of incidence upon said integrator of the ring-like light or of the plurality of lights; and
wherein said first and second deflecting members are provided in a pair demountably mounted.

35. An apparatus according to Claim 34, further comprising means for imaging a pattern of the mask on the substrate.

36. A device manufacturing method including a step of exposing a workpiece to a mask, said method comprising the steps of:

projecting parallel light on a first deflecting surface of conical shape or pyramidal shape to produce ring-like light or a plurality of lights;
projecting the ring-like light or the plurality of lights to form a secondary light source;

wherein in said secondary light source forming step, the ring-like light or the plurality of lights are deflected by a second deflecting surface to reduce the angle of incidence thereof upon the plane; and

projecting divergent lights from portions of the secondary light source obliquely onto the mask so that the lights are superposed one upon another on the mask;

wherein the first and second deflecting surfaces are provided in a pair demountably mounted; and

wherein the parallel light can be projected to an approximately central portion of the plane, when the first and second deflecting surfaces are not present.

37. A method according to Claim 36, wherein a pattern of the mask is imaged on the workpiece.

38. An illumination device, comprising:

5 a light source;
an imaging optical system for imaging said light source, said imaging optical system including (i) parallelizing means for transforming light from said light source into substantially parallel light, (ii) a deflecting member having a light deflecting surface of one of conical shape or pyramidal shape, for receiving the light from said parallelizing means, and (iii) light collecting means for collecting ring-like light or a plurality of lights from said deflecting member into a substantially ring-like shape or a plurality of light spots upon a plane;

10 an optical system for projecting lights from portions of a secondary light source formed by the light from said deflecting obliquely upon a surface to be illuminated so that the lights are superposed one upon another on the surface; and
means for changing the positional relation-

15 ship between an apex of said deflecting surface and the optical axis.

39. An illumination device, comprising:

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a light source;

152. An illumination device comprising:

a light source;

41. A device as claimed in claim 40 wherein for a higher level of resolution at the illuminated surface, an illumination distribution having a dark centre and generally brighter periphery is generated.

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42. A device as claimed in claim 40 or 41, wherein the effective illumination distribution is defined by a deflecting element of the optical system, so as to maintain substantially the efficiency of the optical system.

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43. A device as claimed in claim 40, 41 or 42, wherein the optical system includes an optical integrator whose output forms a secondary light source having the desired distribution.

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44. An illumination device comprising a light source and an optical systems the light source having an effective illumination distribution darker at the centre and generally brighter at the periphery, the optical system including means for converging peripheral portions of the effective illumination onto a surface to be illuminated.

45. An exposure apparatus for exposing a workpiece to a mask, the apparatus including an illumination device as claimed in any of claims 40 to 44 for illuminating the mask with the desired level of resolution, and further comprising a projection system for projecting an image of the illuminated mask onto a workpiece.

46. A device manufacturing method including a step of exposing a work piece to a mask by means of an exposure device as claimed in claim 45, said method including the preliminary step of selecting an effective illumination distribution within the illumination device dependent on a level of resolution desired in the exposure step.

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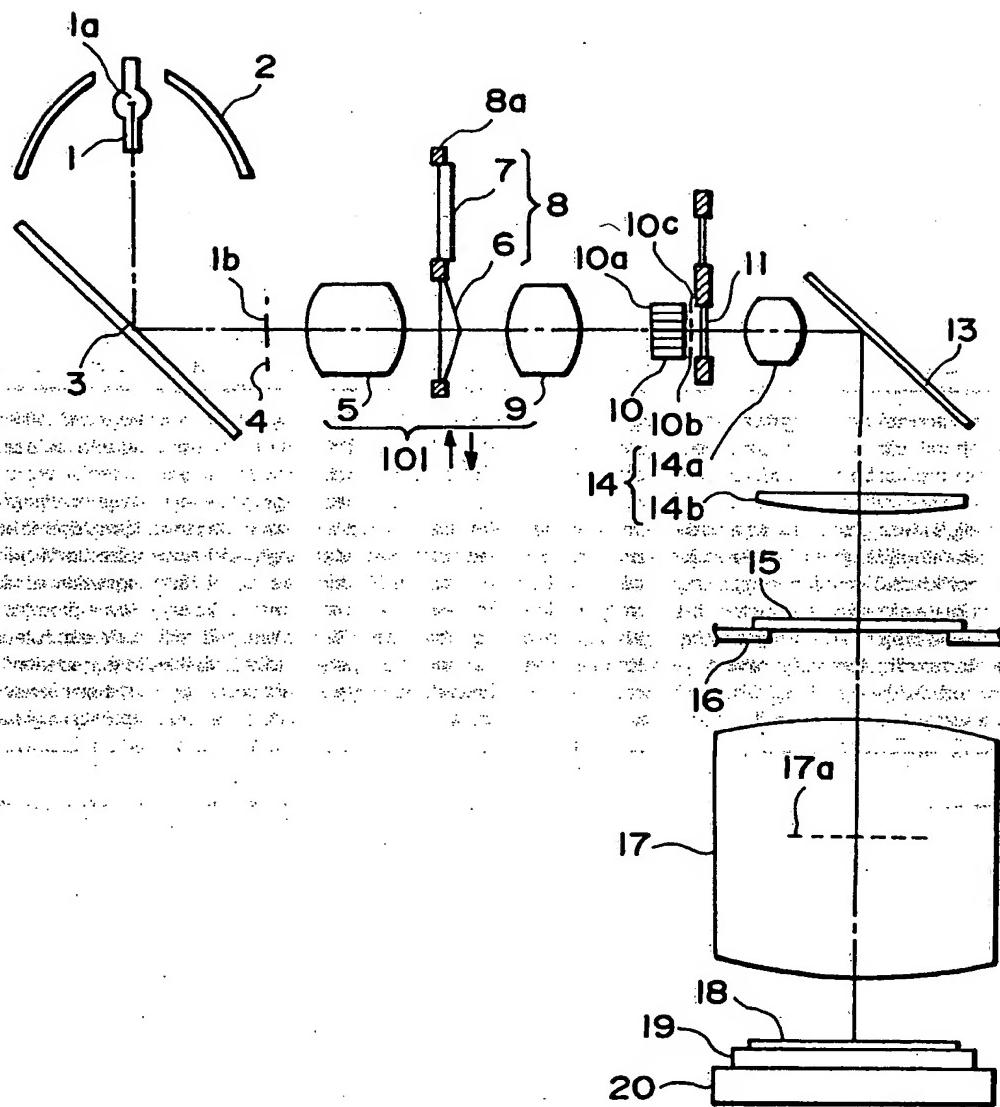


FIG. I

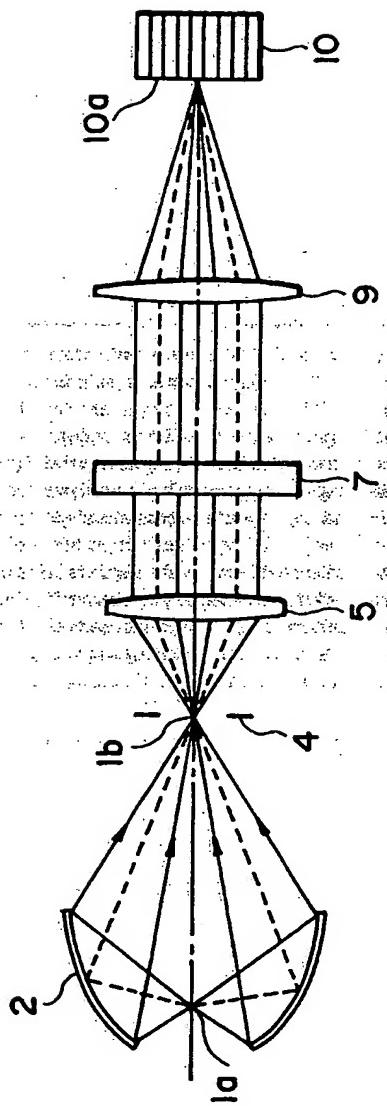


FIG. 2A

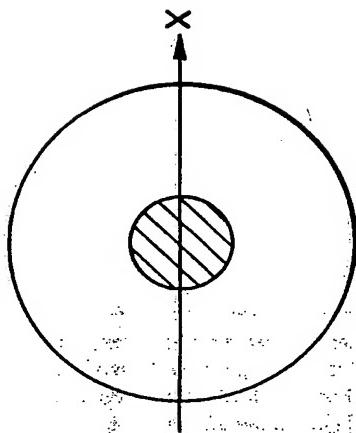


FIG. 2C

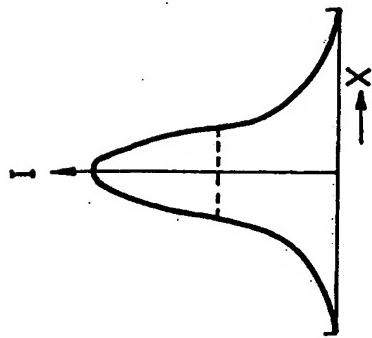
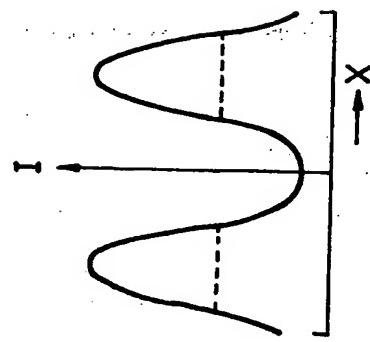
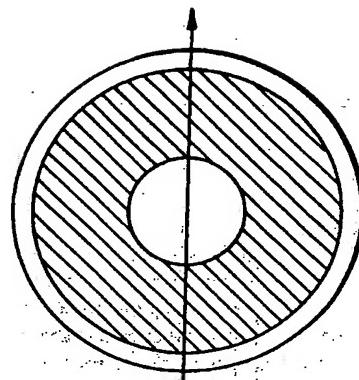
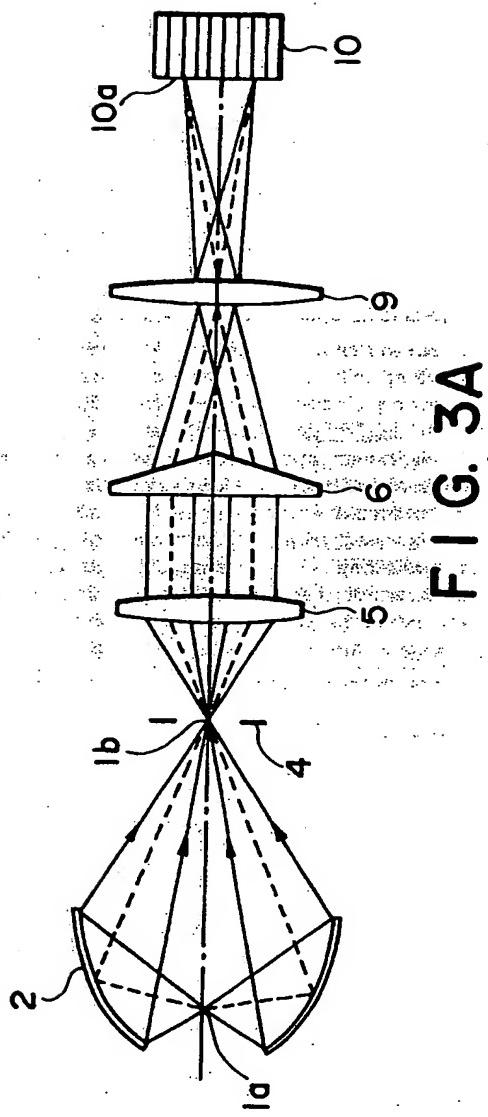


FIG. 2B



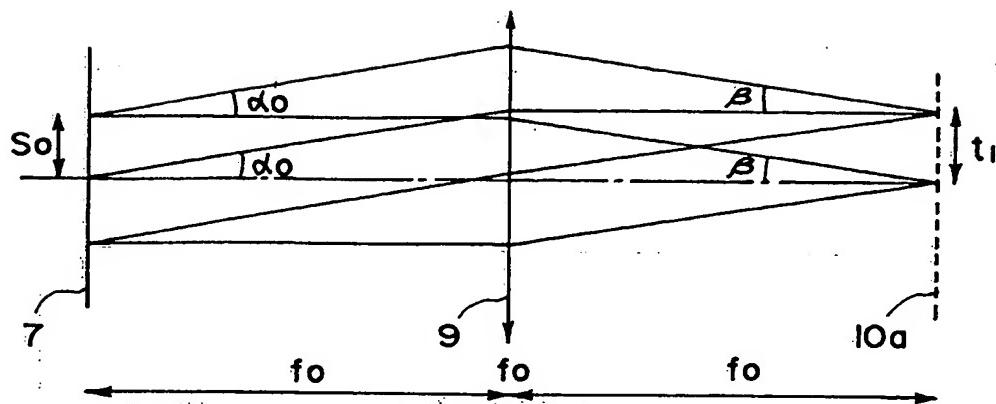


FIG. 4

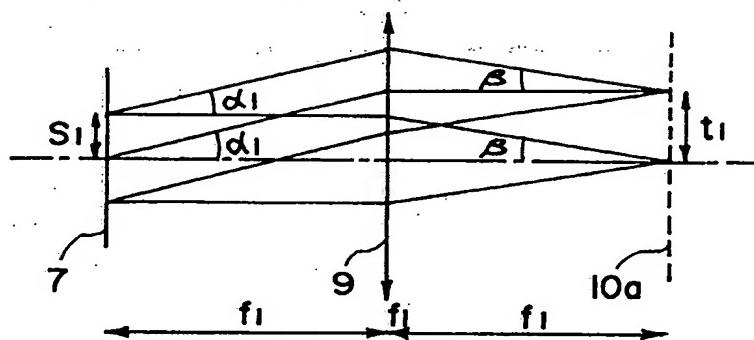
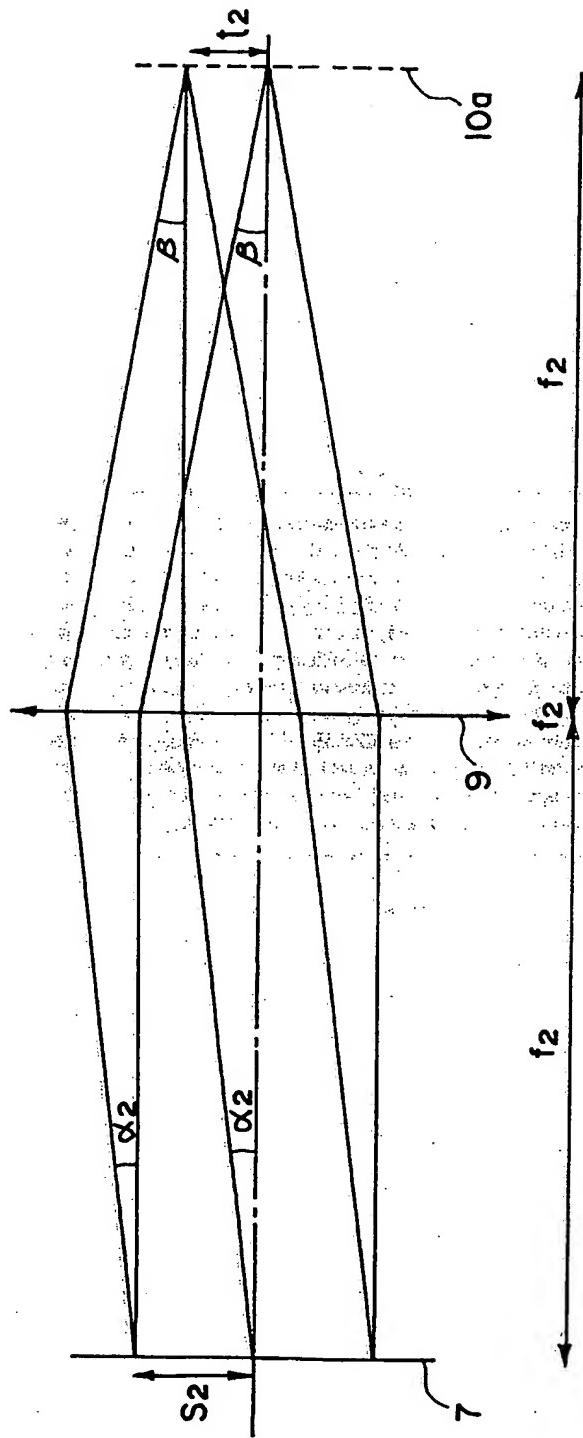


FIG. 5



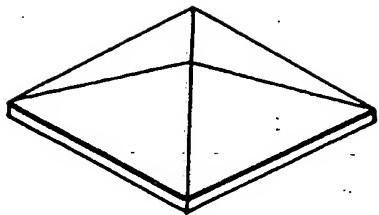


FIG. 7A

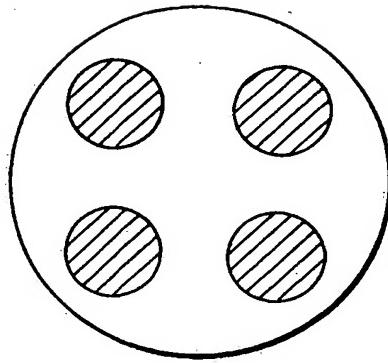


FIG. 7B

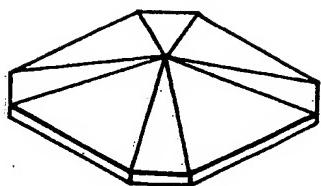


FIG. 8A

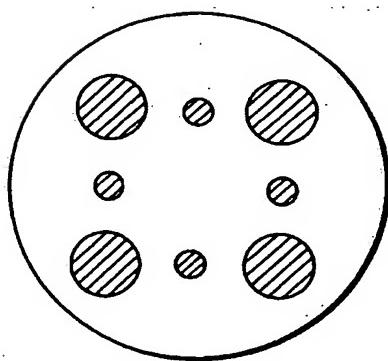
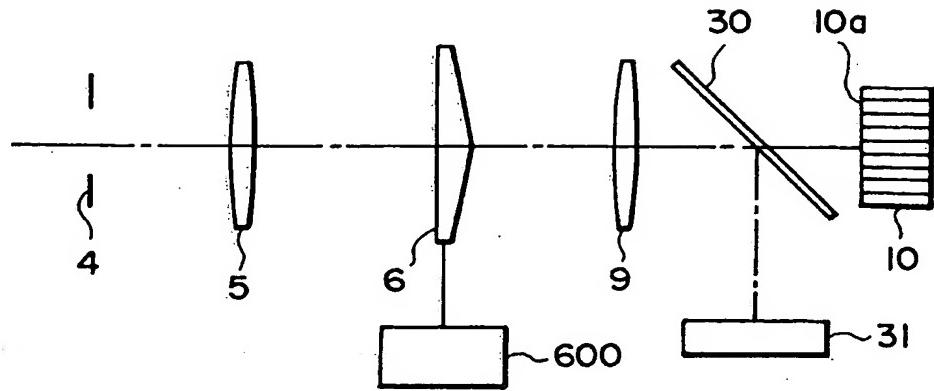
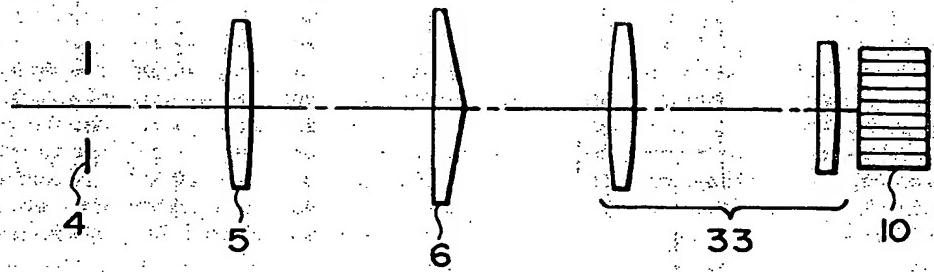


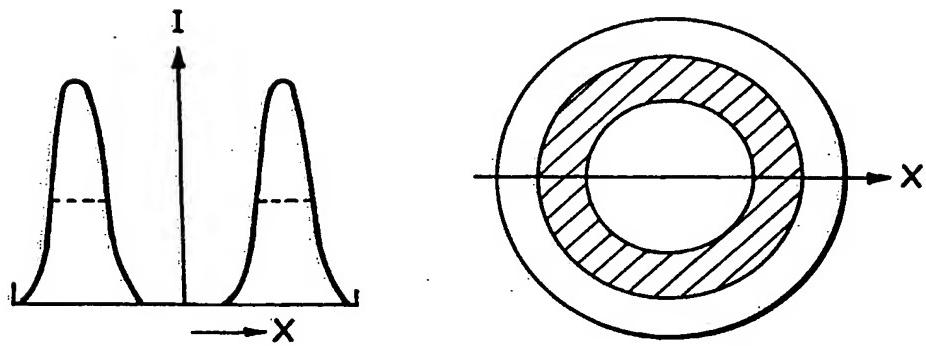
FIG. 8B



F I G. 9



F I G. 10A



F I G. 10B

F I G. 10C

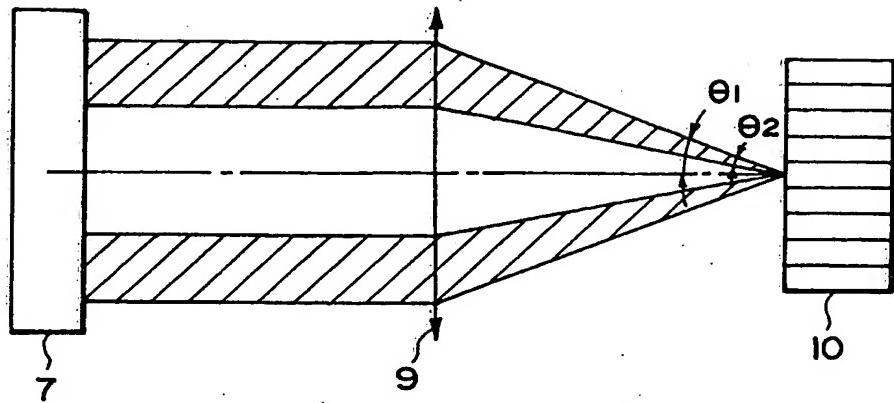


FIG. II A

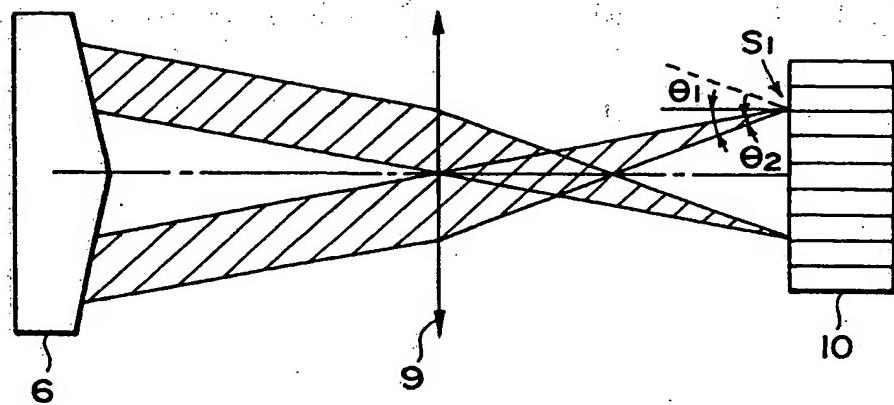


FIG. II B

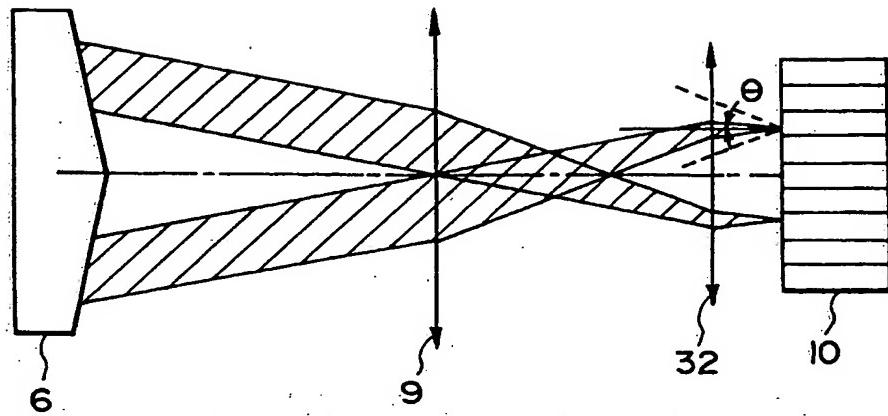


FIG. 12A

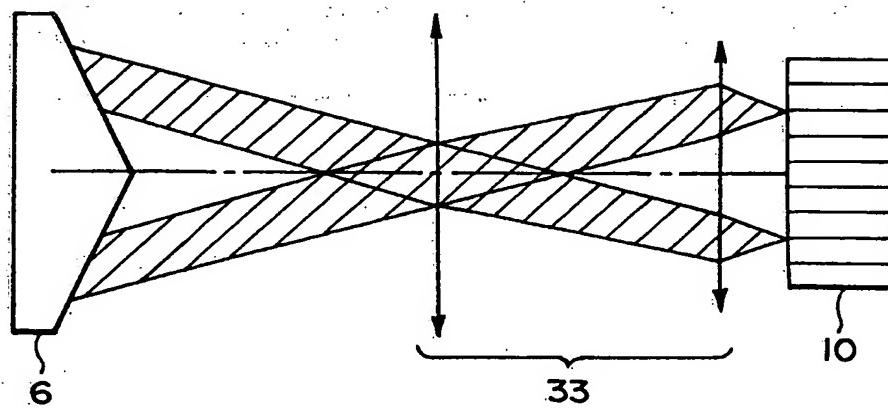


FIG. 12B

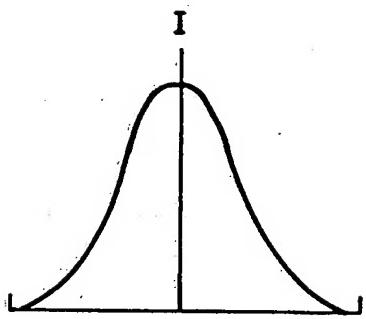


FIG. 13A

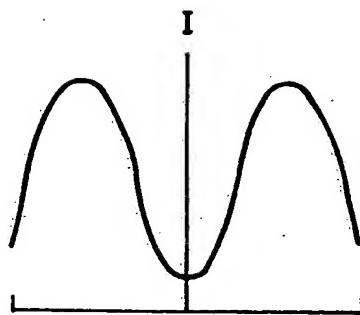


FIG. 13B

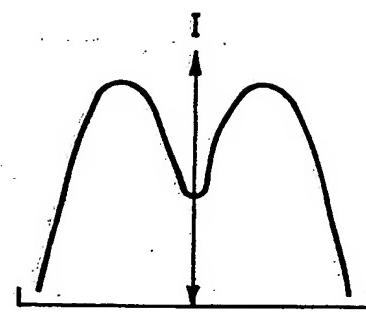


FIG. 14A

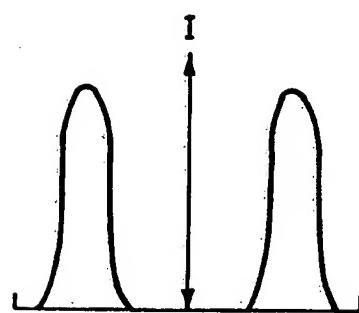


FIG. 14B

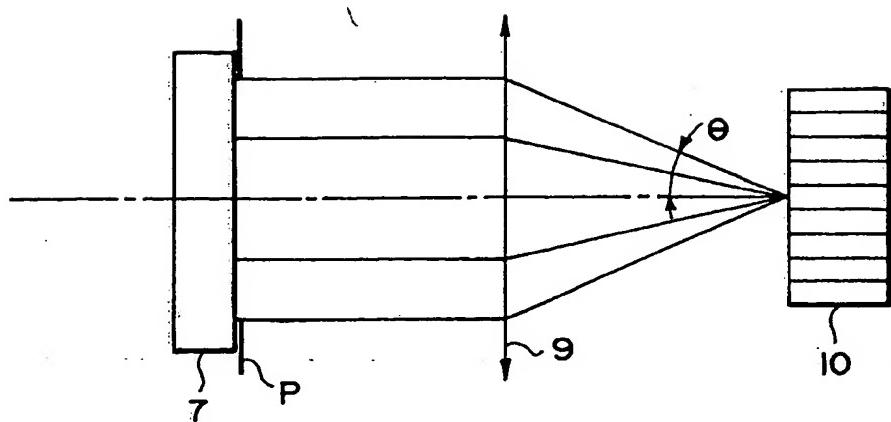


FIG. 15A

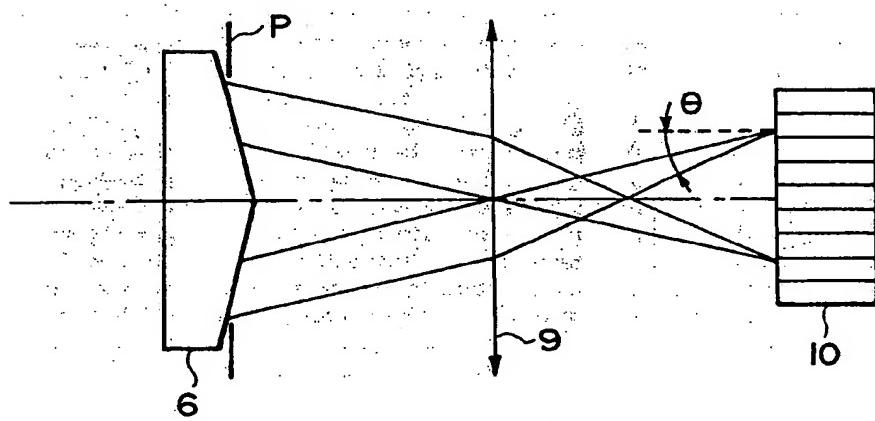


FIG. 15B

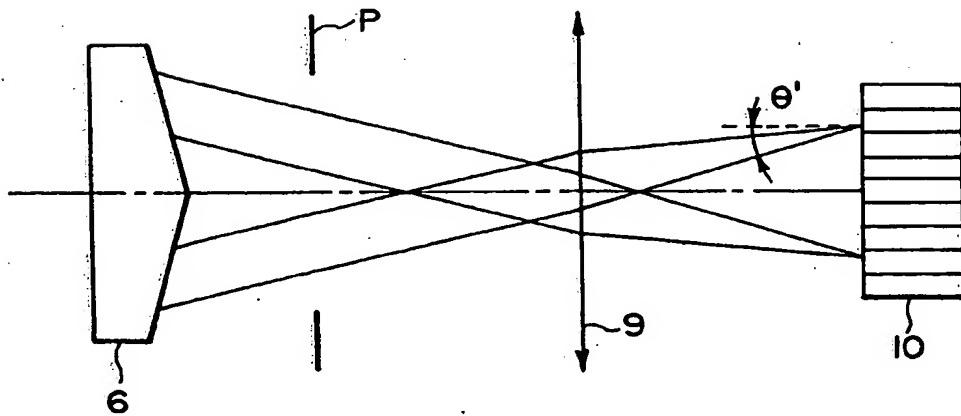


FIG. 15C

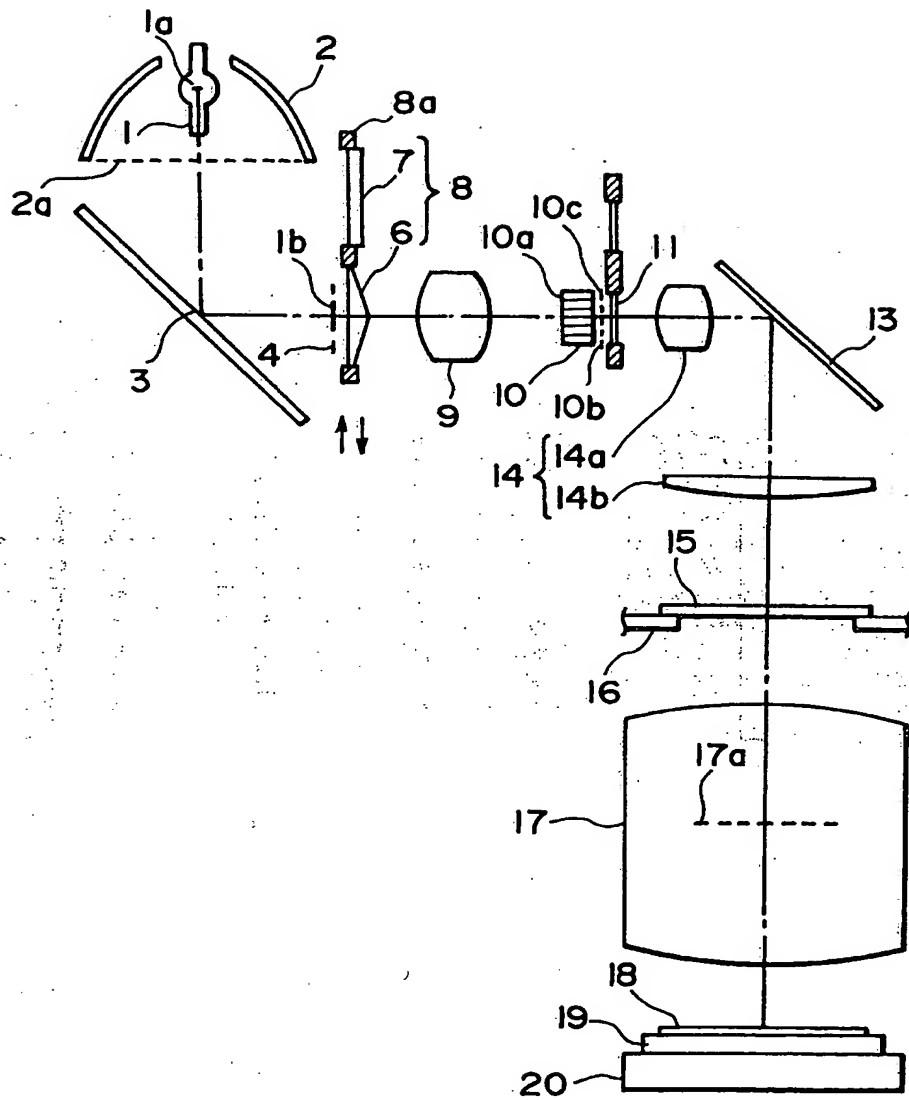


FIG. 16

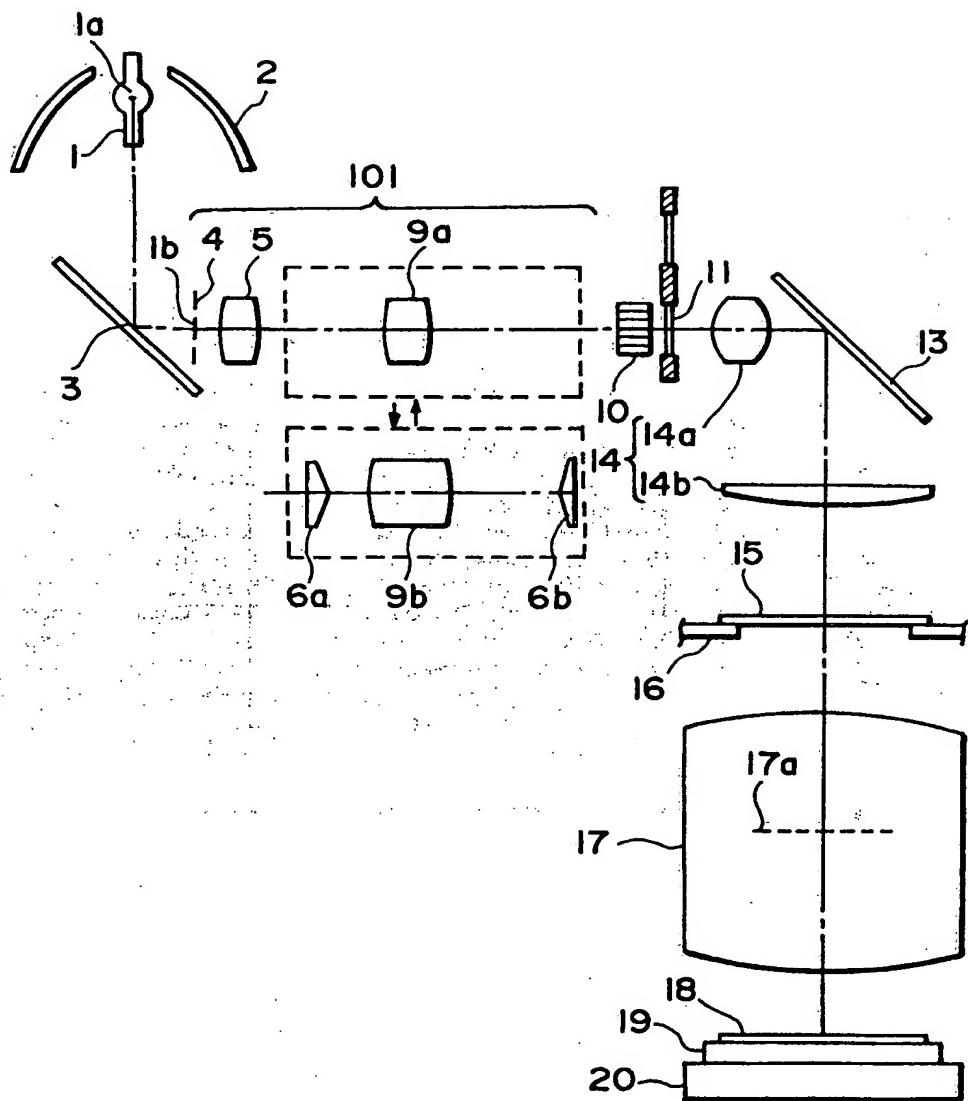


FIG. 17

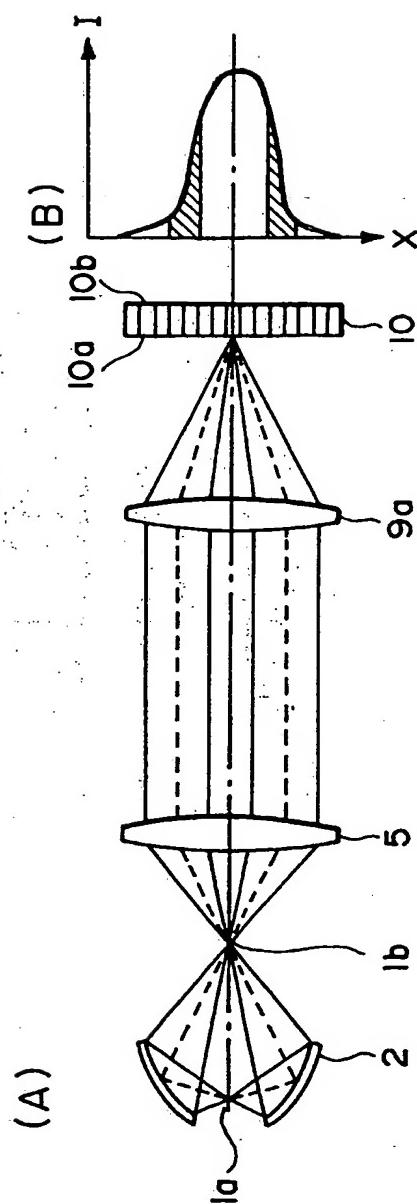


FIG. 18

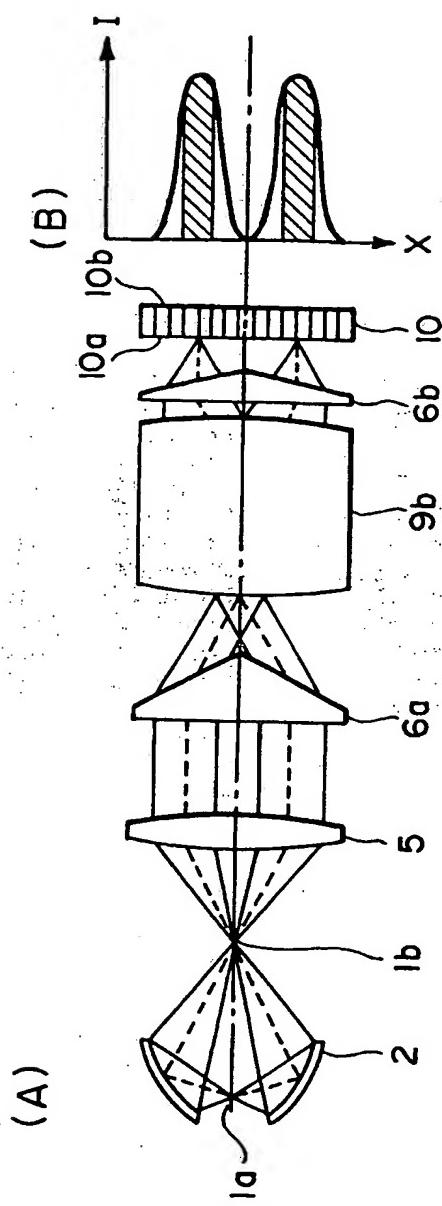
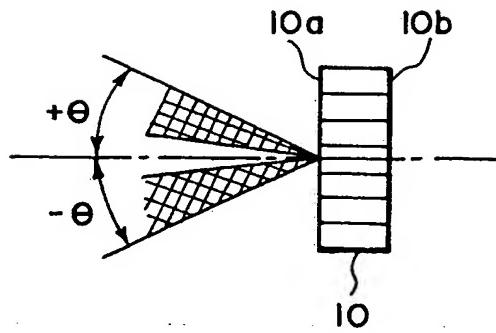
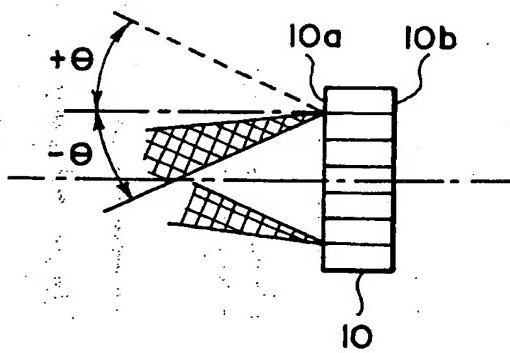


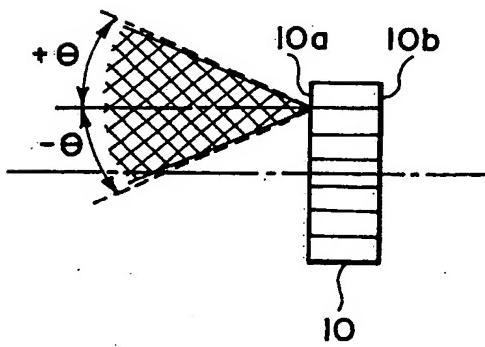
FIG. 19



F I G. 20A

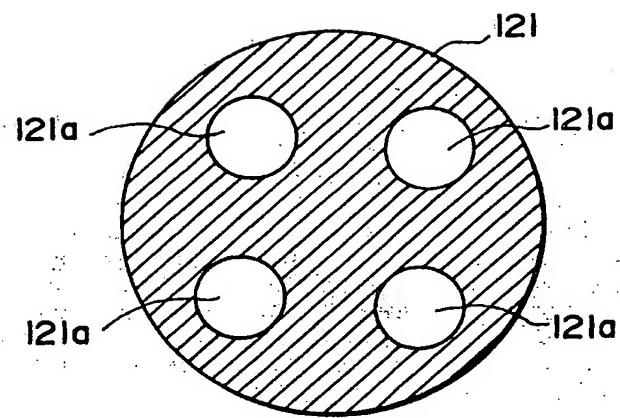


F I G. 20B



F I G. 20C

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F I G. 21

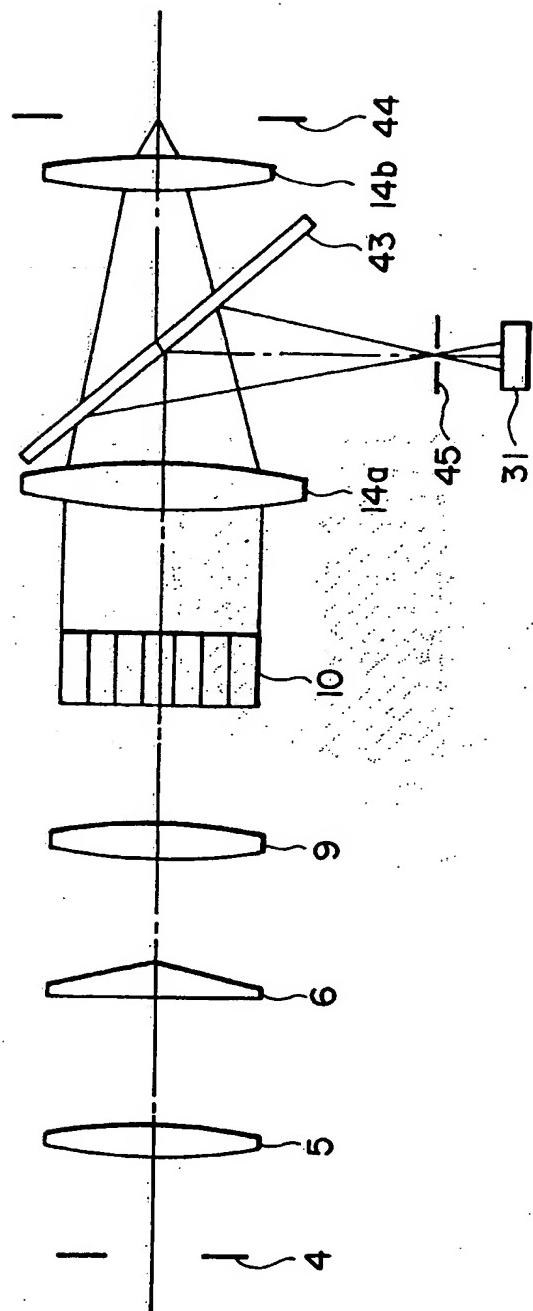


FIG. 22



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 30 2508

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. CL5)	
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	G03F7/20	
X	US-A-4 931 830 (K. SUWA ET AL.) * column 3, line 14 - column 9, line 24 *	40, 42, 43, 45, 46	G03F7/20	
Y	* figures *	41		
A		1, 10, 12, 14, 21, 24, 26, 34, 36, 38, 39		
X	JAPANESE JOURNAL OF APPLIED PHYSICS vol. 30, no. 11B, November 1991, TOKYO JP pages 3021 - 3029 , XP263405 K. KAMON ET AL. 'Photolithography System Using Annular Illumination'	44		
Y	* the whole document *	41		
A		1, 10, 12, 14, 21, 24, 26, 34, 36, 38, 39	TECHNICAL FIELDS SEARCHED (Int. CL5)	
A	US-A-3 795 446 (J.K. HOUSTON) * column 4, line 39 - column 8, line 33; figures *	1, 10, 12 14, 21, 24, 26, 34, 36, 38, 39	G03F	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 125 (P-847)28 March 1989 & JP-A-63 293 547 (N I K O N C O R P) 30 November 1988 * abstract *	1, 10, 12, 14, 21, 24, 26, 34, 36, 38, 39		
The present search report has been drawn up for all claims				
Place of search	Date of completion of the search	Examiner		
THE HAGUE	01 JUNE 1993	HERYET C.D.		
CATEGORY OF CITED DOCUMENTS		I : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document		
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document				